Phytoplankton Distributions in Relation to Mesoscale Physical Processes

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LONG TERM GOALS

The principal goal of my research is to understand the mechanisms by which physical processes regulate spatial distributions of marine plankton. This effort has concentrated on quantifying the spatial and temporal distributions of phytoplankton, and more recently zooplankton, in relation to physical processes that mediate advection and dispersion, as well as nutrient input to the euphotic zone and the depth of the mixed layer.

OBJECTIVES

The primary objective of my research has been to interpret pigment distributions, as well as phytoplankton growth and productivity, in relation to mesoscale eddies. Field studies have concentrated on eddies associated with western boundary currents and mesoscale processes on continental shelves.

Recently we have developed methods to follow the dispersal of coastal and estuarine phytoplankton and zooplankton populations in relation to physical processes at sub-mesoscale dimensions. Here the objective has been to relate short-term (day-to-week) dispersal patterns in relation to winds, tides, and currents in coastal environments.

APPROACH

The general approach has been to quantify the spatial variability and follow the temporal development of plankton populations from a Lagrangian perspective. This has relied upon the development of expendable autonomous surface drifters instrumented with solid-state fluorometers to measure an index of phytoplankton biomass. More recently, we have developed methods to map phytoplankton and zooplankton distributions in evolving tracer fields. This approach is to quantify the spatial variability in plankton biomass within a developing tracer ‘patch’. As the tracer fields evolve, spatial distributions of plankton populations are mapped simultaneously with properties in the mixed layer (temperature, salinity, and nutrients).

WORK COMPLETED

In August 1995 we surveyed phytoplankton distributions in a cool filament extending offshore from an upwelling zone at the Somali coast. This filament wrapped around the northern edge of the Great

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Whirl, an anticyclonic eddy that develops each year during the summer monsoon in the northern Arabian Sea. Surface properties (T, S, nutrients, and chlorophyll *a*) and velocity (Acoustic Doppler Current Profiler) maps, as well as XBT and CTD casts, were related to the trajectories of three instrumented surface drifters to describe the history of upwelled waters (Hitchcock *et al*., in review).

Two field studies have been completed to evaluate methods for interpreting the dispersion of plankton in tracer fields. In 1996 we mapped the surface plankton distributions on a subtropical shelf following the release of the intentional tracer sulfur hexafluoride (Hitchcock *et al*., in review). In 1998 experiments were conducted with a combination of surface drifters and the fluorescent tracer Rhodamine WT to follow the dispersal of a larval patch following an intentional release in an estuary.

RESULTS

Surface pigment distributions off the coast of Somalia reveal that during the summer monsoon phytoplankton are rapidly advected offshore from upwelling centers. Surface drifters deployed within the surface filament that encircled the Great Whirl were rapidly advected offshore. Surface property fields show that the upwelled waters are transported offshore to the Socotra eddy. Current velocities derived from a ship-mounted ADCP indicate that surface velocities exceeded 100 cm s^{-1} in the filament, with maximum velocities > 200 cm s^{-1} at the edge of the eddy. Time scales at which fluorescence (< 5 days), surface temperature (> 10 days), and velocity components (*u, v*) decorrelate (from drifter records) suggest phytoplankton maxima in the upwelling zone are rapidly dispersed with contiguous surface waters (Hitchcock *et al*. in review).

Spatial distributions of plankton larvae in a shallow estuary were mapped in relation to the dispersal pattern of Rhodamine WT, a fluorescent dye, and surface drifters. Approximately 2.5 x 10^8 shellfish larvae were released in the Indian River lagoon; the motion of the drifters indicated that larvae should have settled within the shallow northern end of the embayment. Winds were the primary forcing influencing the advection and dispersion of the larval patch. Dye releases on successive days confirmed that dispersion coefficients were 2 – 3 fold greater in the downwind than in the crosswind axis of the patch. Currently, larvae are being counted from water samples taken in the lagoon during the release experiment. These will indicate if the predicted spatial distributions based on the surface drifter and dye observations are valid.

IMPACT/APPLICATIONS

Our principal contribution to the study of biological oceanography has been to quantify variability in plankton populations from a Lagrangian reference frame. Since phytoplankton and zooplankton are Lagrangian followers of water motion in the horizontal, our ability to map plankton spatial distributions in water parcels permits us to follow the temporal evolution of ‘tagged’ populations. These methods are well suited to describe the dynamics of plankton populations in energetic regions such as eddies, coastal and nearshore environments.

TRANSITIONS

The expendable, instrumented surface drifter has been incorporated into a subset of the Surface Velocity Program of the World Ocean Circulation Experiment (WOCE). Several drifters have been provided to supplement the SVP effort with surface fluorescence measurements.

RELATED PROJECTS

Instrumented surface drifters have been deployed to study shelf-estuarine exchange processes on the West Florida Shelf in conjunction with G. Vargo (Univ. of S. Florida). The objective of this study is to determine the role of freshwater nutrient sources in sustaining phytoplankton blooms at the shelf-estuarine boundary.

Additionally, a combination of instrumented drifters and intentional tracer releases have been incorporated into a study of sub-mesoscale vorticities along the shoreward edge of the Florida Current. The objective of this NOAA-sponsored program is to document offshore advection from the Florida reef tract to oceanic waters. This is a cooperative effort with T. Lee and S. Smith (Univ. of Miami) and P. Ortner (AOML/NOAA).

PUBLICATIONS

Hitchcock, G. L., G. A. Vargo, and M.-L. Dickson. In review. Phytoplankton growth and production in relation to dissolved inorganic carbon on the West Florida Shelf, April 1996. Submitted to J. Geophys. Res.

Hitchcock, G. L., E. L. Key, and J. Masters. In review. Upwelled waters associated with the Great Whirl, August 1995. Submitted to Deep-Sea Res.